Modeling stick-slip motion of ice streams

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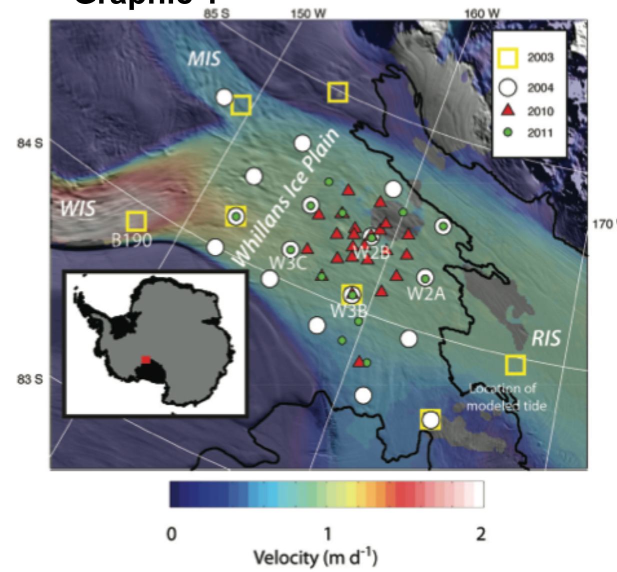
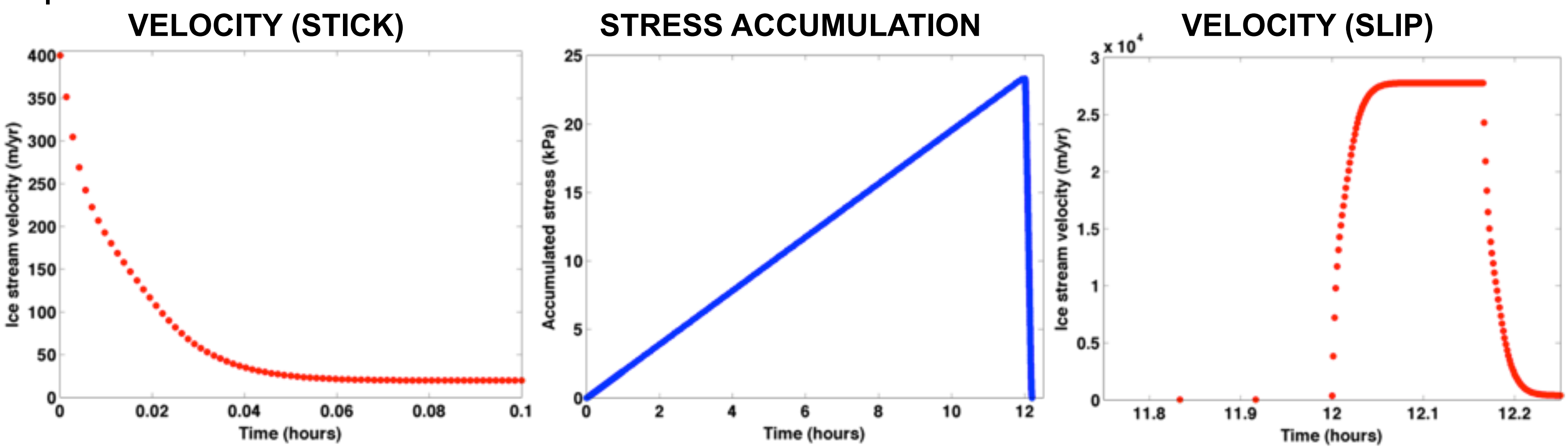
Modeling of transient flow variations like stick-slip events allows inference of physical properties and provides insight regarding physical processes. This study is a step forward towards understanding how ice streams slide over their beds, which is critical for modeling ice sheet mass balance and potential contributions to sea level rise.

Graphic 1



Graphic 2



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References:

Additional collaborators: Profs. Byron R. Parizek and Richard B. Alley, Pennsylvania State University

Full citation: Walker, R.T., B.R. Parizek, R.B. Alley, and S.M.J. Nowicki, 2016. A viscoelastic model of ice stream flow with application to stick-slip motion. *Frontiers in Earth Science*, 4:2. doi:10.3389/feart.2016.00002.

Other works cited: Bindschadler, R.A., and 27 others including S.M.J. Nowicki and R.T. Walker, 2013. Ice-sheet model sensitivities to environmental forcing and their use in projecting future sea level (the SeaRISE project). *Journal of Glaciology*, 59(214),195-224. doi:10.3189/2013JoG12J125.
Winberry, J.P., S. Anandakrishnan, R.B. Alley, D.A. Wiens, and M.J. Pratt, 2014. Tidal pacing, skipped slips and the slowdown of Whillans Ice Stream, Antarctica. *Journal of Glaciology*, 60(222), 795-806. doi:10.3189/2014JoG14J038.

Data Sources: Winberry et al., 2014 and J.P. Winberry, personal communication.

Technical Description of Figures:
Graphic 1: While most ice streams flow steadily, some (such as Whillans; see map) advance only in short bursts as “sticky spots” at their beds repeatedly strengthen slowly (hours) and break quickly (minutes). We simulate this behavior with a new 2D map-plane viscoelastic model of ice stream flow. This is a the map of the Whillans Ice Plain (WIP) from Winberry et al., 2014 showing ice velocities and their instrument locations.
Graphic 2: Along-flow velocity over sticky spot (meters per year) and maximum accumulated stress (kiloPascals) for stages of stick-slip motion on idealized WIP as simulated by Walker et al., 2016. Values extracted from two-dimensional map plane model output. (Left) As sticking begins, ice flow over sticky spot quickly comes to a (near) halt. (Center) As sticking continues for 12 hours, velocity stays constant and a large stress accumulates before releasing when the sticky spot breaks. (Right) As sticky spot breaks over 10 minutes, release of stress leads to rapid slipping, with ice flow over (former) sticky spot reaching over 50 times mean velocity.

Scientific significance, societal relevance, and relationships to future missions: Fast-flowing ice streams drain the Antarctic Ice Sheet into the ocean, so understanding their dynamics is critical for projections of sea-level rise (e.g., Bindschadler et al., 2013) and interpreting elevation changes detected by altimetry missions (ICESat, IceBridge, ICESat-2). This work is a step towards understanding how ice streams slide over their beds, a major but poorly understood process. The new model will enable testing of observation-based parameterizations of sliding in future work.

Estimation of surface evaporative fraction using easily obtainable variables from Landsat and MODIS

Ali L. Yagci and Joseph A. Santanello, Hydrological Sciences, NASA GSFC

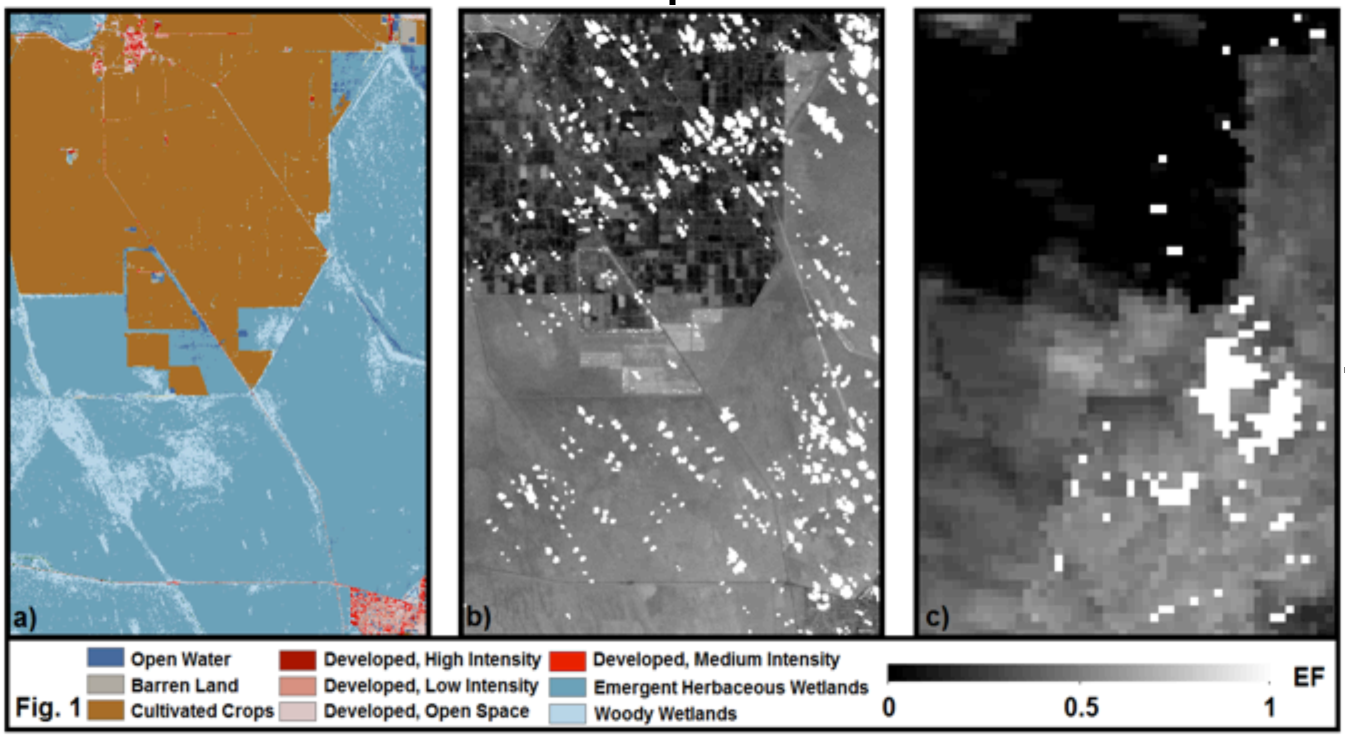

Fig. 1

Land Cover

Evaporative Fraction - Landsat

Evaporative Fraction - MODIS

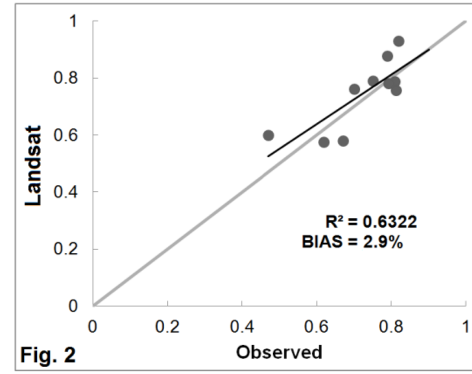

Fig. 2

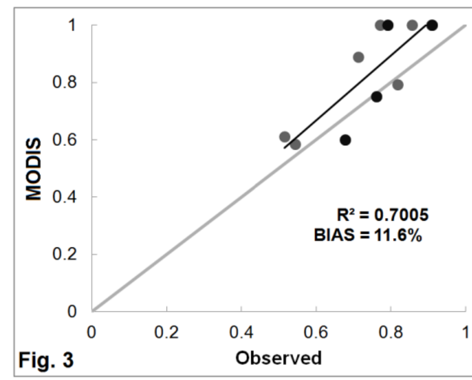

Fig. 3

Evaporative Fraction (a ratio of evapotranspiration to total available energy), which is highly variable yet important for monitoring and evaluating the water budgets of agricultural and natural ecosystems, can be readily estimated from satellite imagery.

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Acknowledgments and References:
•The initial research with the Landsat products started with the support of **John W. Jones** from USGS Eastern Geographic Science Center
•This research is supported by NASA Postdoctoral Program at the Goddard Space Flight Center
•**Yagci, Ali Levent, and John W. Jones. 2014**. "Fully-Automated Estimation of Actual to Potential Evapotranspiration in the Everglades Using Landsat and Air Temperature Data as Inputs to the Vegetation Index-Temperature Trapezoid Method." In American Geophysical Union (AGU) 2015 Fall Meeting. San Francisco, CA, USA: AGU. https://agu.confex.com/agu/fm14/meetingapp.cgi#Paper/18583.
•**Yagci, Ali Levent, Joseph A. Santanello, and John W. Jones. 2016**. "A Satellite-Based Evapotranspiration Retrieval over Local-to-Global Scales in Support of Land Surface, Hydrological, Mesoscale, and Global Climate Models." In 96th American Meteorological Society (AMS) Annual Meeting. New Orleans, LA, USA: AMS. https://ams.confex.com/ams/96Annual/webprogram/Paper288918.html.

Data Sources:
•The Moderate Resolution Imaging Spectroradiometer (MODIS), flown on two NASA spacecrafts, Terra and Aqua. MODIS collects observations with 1-km ground sample distance two times a day around 11:30 (Terra) and 13:00 (Aqua).
•The Thematic Mapper (TM), flown on Landsat 5 satellite. The Landsat 5 satellite collected observations every 16 days with 30-m ground sample distance around 10:40 in the morning. Although It is no longer in orbit, Landsat 7 and 8 satellites are currently in orbit.
•Daily 1-km maximum air temperature from the Daily Surface Weather and Climatological Summaries (DAYMET) dataset.
•Surface energy fluxes are routinely collected every 30 minute using eddy covariance method at the flux tower in the Everglades National Park. The flux tower is registered in FLUXNET and AmeriFlux flux tower networks with the ID, US-Skr.
•A model developed using the vegetation index-temperature trapezoid (VITT) in Python programming language to estimate Evaporative Fraction (EF) from standard satellite products such as Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) and meteorological inputs such as daily maximum air temperature. These products are readily available to public at no cost.

Technical Description of Figures:
Figure 1a: Land cover/Land use map of the subset area from the National Land Cover Database of 2011.
Figure 1b: Landsat-based EF map of agricultural fields and wetlands along the northern part of the Everglades National Park on February 21, 2009.
Figure 1c: MODIS-based EF map of agricultural fields and wetlands along the northern part of the Everglades National Park on February 21, 2009.
Figure 2: Comparison between observed Evaporative Fractions at the flux tower and estimated Evaporative Fractions in 2009. The model is run with the satellite images acquired by the Thematic Mapper sensor onboard the Landsat 5 satellite. Observed energy fluxes collected at the flux tower, US-Skr, are used to validate the model outputs.
Figure 3: Same as Fig. 2, except the model is run with the satellite images acquired by the MODIS sensor onboard Terra satellite.

Scientific significance, societal relevance, and relationships to future missions:
Freshwater resources are becoming more and more scarce as the world population continues to grow steadily. Water managers, decision makers and government agencies demand tools to effectively measure water consumption by agriculture and natural ecosystems. Here, we developed a model to map evaporative fraction and subsequently evapotranspiration in both time and space from infrequent fine resolution satellite images (e.g., Landsat) for agricultural water use monitoring as well as frequent coarse resolution satellite images (MODIS) for balancing the water budgets of ecosystems (e.g., the Everglades National Park). The model is capable of making a great use of the NASA's current missions such as the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting satellite and future missions like the ThermaSat.

Networking of automated ground measurements for sensor calibration

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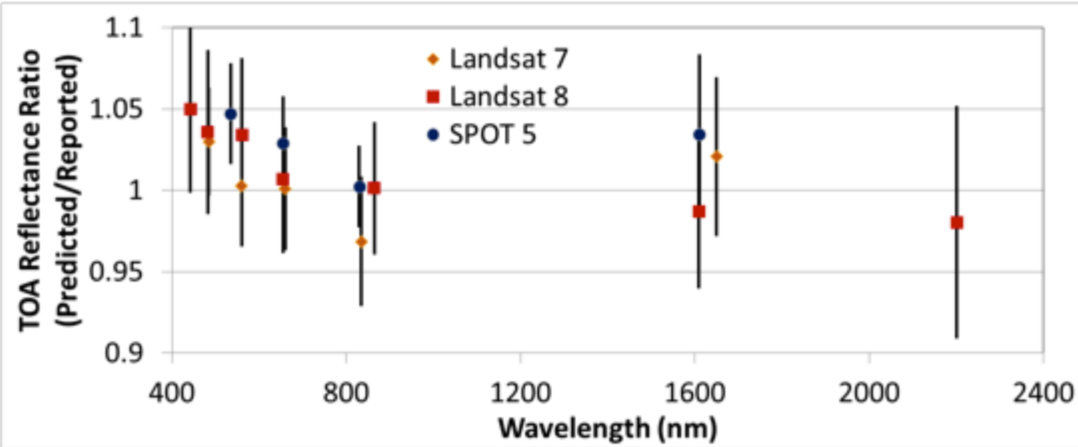
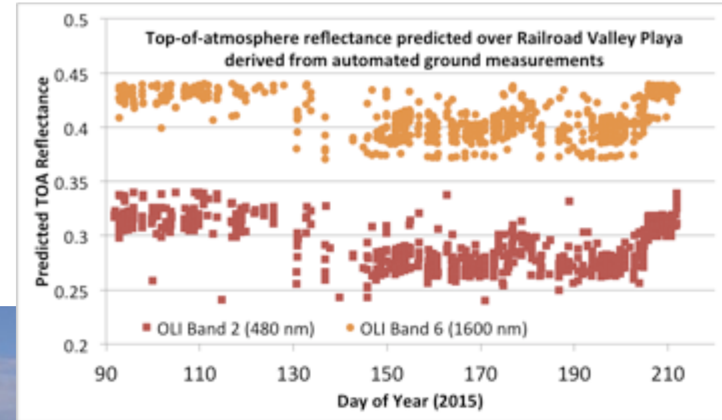
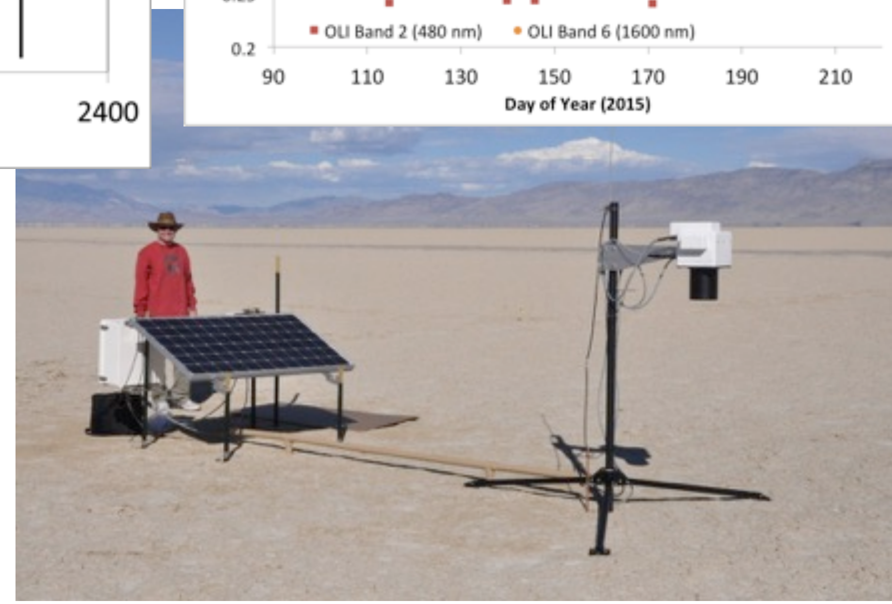
[1]Biospheric Sciences, NASA GSFC and SSAI, [2]University of Arizona







Networked vicarious calibration will provide an additional tool that is highly suited for an expected rise in the number of imagers over the next decade (including research sensors, small-sats, constellations, and commercial systems)

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References:
Czapla-Myers, J., K. J. Thome, N. Anderson, and S. Biggar. 2014. "The absolute radiometric calibration of Terra imaging sensors: MODIS, MISR, and ASTER." Proceedings of SPIE 9218 [10.1117/12.2062529]

Data Sources:
MODIS, MISR, ASTER, ETM+, OLI, SPOT-5 HRVIR, AERONET

Technical Description of Figures:
Graph 1: Ratio of top-of-atmosphere reflectance predicted from automated ground-based measurements to those reported by three sensors while viewing the Railroad Valley Playa, Nevada. Predicted values are based on a simulation of expected networked results based on downsampled temporal and spectral data.

Graph 2: Top-of atmosphere reflectance from spring/summer of 2015 derived from the hyperspectral predictions for two Landsat 8 bands. Graph shows 13 data points per day at 30 minute intervals. Gaps are due to cloudy periods. Scatter is caused by surface BRDF effects and unfiltered cloud effects. Apparent shift in reflectance around DOY 150 is a known effect caused by wind erosion removing a bright salt deposit from winter percolation.

Image1: Photograph showing ground-viewing radiometer that is the key to assessing surface reflectance of the test site. Not shown is the AERONET sensor that provides atmospheric information. Equipment is maintained and operated by the Remote Sensing Group of the College of Optical Sciences at the University of Arizona.

Images2, 3: Figures show the RapidEye constellation and a cartoon of current LEO objects currently being tracked by the US Air Force. Figures are to emphasize the difficulties that are expected as we attempt to characterize a larger number of sensors as we move towards distributed missions, constellation approaches, commercial providers, and broader international participation.

Scientific significance, societal relevance, and relationships to future missions:
As the number of Earth-observation satellites is ever increasing, one of the challenges for the scientific community is to ensure that the absolute radiometric calibration of these sensors resides on the same SI-traceable scale. Individual teams, equipment, and sites are typically used to assess the post-launch radiometric calibration of each instrument by simulating top-of-atmosphere signals from in-situ surface and atmosphere measurements. Such assessment based on a single site/instrumentation can lead to radiometric biases between satellite sensor radiometry.
The Radiometric Calibration Network (RadCalNet) working group (WG) (formerly known as Landnet) as part of the Committee on Earth Observation Satellite's Working Group on Calibration and Validation is currently working on a prototype methodology that seeks to minimize calibration biases by creating a standardized network of sites and data processing protocols. Such a network approach will also greatly improve the temporal frequency at which an EO sensor radiometric accuracy can be assessed.
The Railroad Valley Playa results shown here are being used to help define the protocols needed for RadCalNet data collections and processing. Future efforts will include additional sensors as well as combining data from additional test sites. Making predictions of top-of-atmosphere reflectance available to a wide user community will allow satellite providers from developing countries and commercial providers to place their sensor's data products on similar radiometric scales to NASA assets allowing NASA users access to more consistent data sets for data fusion.

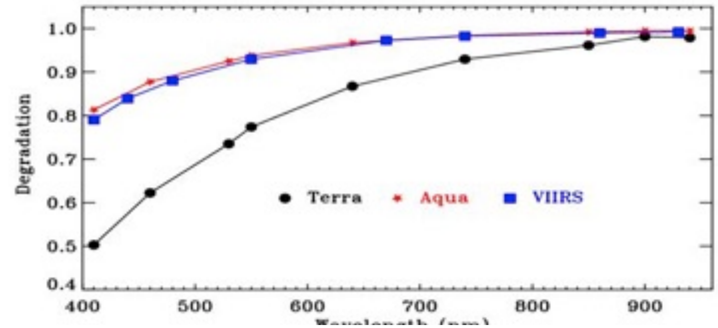
Initial Studies of the Directional Reflectance Changes in Pressed and Sintered PTFE Diffusers Following Exposure to Ionizing Radiation

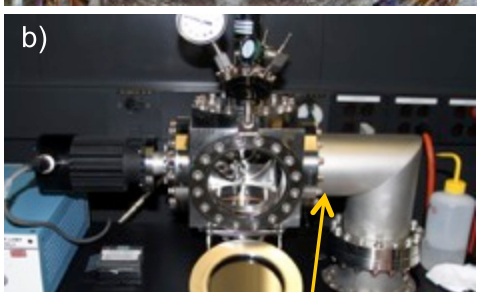
Jim Butler[1], Georgi Georgiev[2]

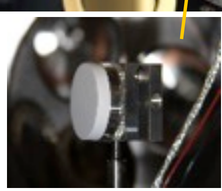
[1]Biospheric Sciences, NASA GSFC; [2]Biospheric Sciences, NASA GSFC and SSAI

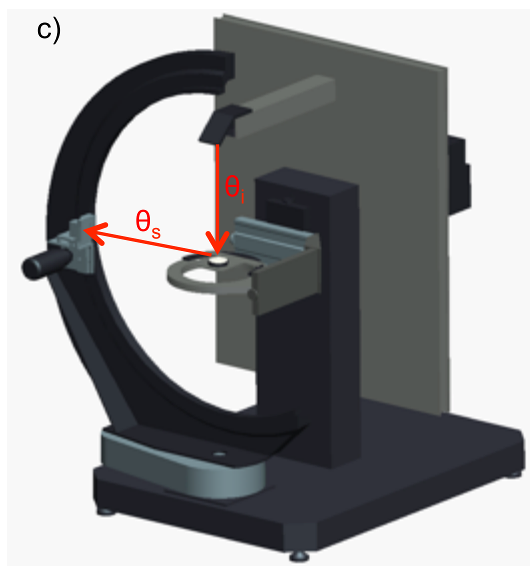
Polytetrafluoroethylene (PTFE, a.k.a. Spectralon™) solar diffusers, commonly used in the on-orbit radiance calibration of visible through shortwave infrared remote sensing instruments, experience wavelength-dependent reflectance degradation over time.

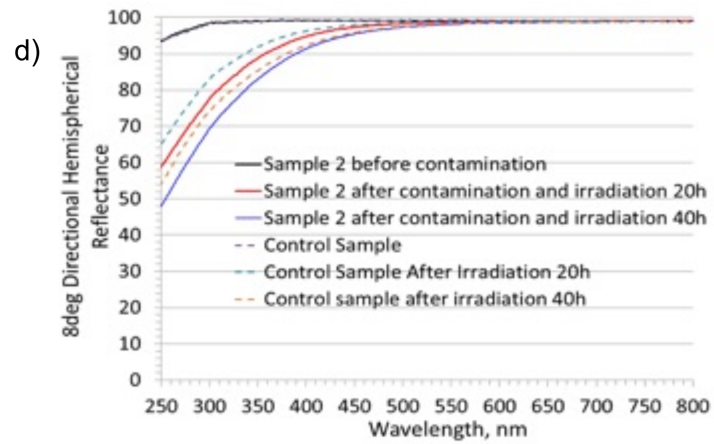
Our laboratory assessments of the effects of VUV irradiation on diffuser reflectance provide quantitative insight into the on-orbit degradation

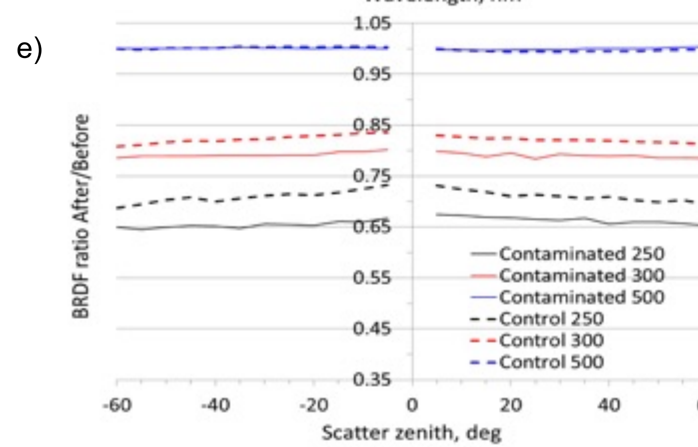












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References:

G.T. Georgiev, J.J. Butler, K.J. Thome, L.A. Ramos-Izquierdo, L. Ding, L.J. Graziani and G.A. Meadows, ''Initial studies of the directional reflectance changes in pressed and sintered PTFE diffusers following exposure to contamination and ionizing radiation", Metrologia **51** (2014) S319–S328, doi: 10.1088/0026-1394/51/6/S319

Data Sources: NASA GSFC Code 618 Diffuser Calibration Laboratory (DCaL) PTFE Bidirectional Reflectance Distribution Function (BRDF) and Directional Hemispherical Reflectance (DHR) Measurement Data; NIST BRDF Calibration reports; MODIS Terra and Aqua and SNPP VIIRS Solar Diffuser Degradation Data;

Technical Description of Figures:

Top Figure: On-orbit reflectance degradation of MODIS Terra, MODIS Aqua, and SNPP VIIRS PTFE diffusers from launch to September 2015.

Bottom Figure: NASA GSFC Diffuser Calibration Laboratory-based experimental procedure to examine the reflectance degradation of PTFE diffusers as a function of contamination and vacuum ultraviolet exposure. a) The thermal vacuum bakeout/contamination chamber: All PTFE samples undergo initial vacuum bakeout followed by the option of contamination/deposition (i.e. 45Å) of Pennzane™, a common spacecraft lubricant. b) The oil-free vacuum ultraviolet (VUV) exposure chamber: Contaminated and uncontaminated PTFE samples are mounted in the chamber and irradiated by the black VUV light source on the left. c) The PTFE samples are measured for BRDF before and after bakeout, contamination, and VUV exposure using the DCaL's out-of-plane scatterometer and for Directional Hemispherical Reflectance (DHR) using the DCaL's Perkin Elmer spectrophotometer. d) DHR versus wavelength data for contaminated (i.e. sample 2) and non-contaminated (control) samples before and after 20 and 40 hours of VUV irradiation. e) Ratio of the normal incident (BRDF at 250nm, 300nm, and 500nm before and after 20 hours VUV irradiation for contaminated sample 2 and the control.

Scientific significance, societal relevance, and relationships to future missions:

On-orbit calibration of Earth remote sensing instruments is required to discriminate between instrumental changes and changes in earth physical processes under study. The majority of remote sensing instruments operating in the visible through shortwave infrared wavelength region employ solar illuminated diffusers for on-orbit radiance calibration. Polytetrafluoroethylene (PTFE), also known as Spectralon™, is a white, near-Lambertian, diffuse scattering material commonly used for this purpose. Unfortunately, the presence of on-orbit contaminants coupled with incident solar radiation at ultraviolet wavelengths, leads to wavelength dependent degradation of the reflectance of PTFE diffusers.

The work presented here is part of a larger study designed to examine PTFE reflectance degradation as a function of wavelength of incident light, mission solar exposure time, and contaminant amount. Bruegge and Stiegman (1) examined the aging of PTFE deployed on the Space Shuttle but did not examine its dependence as a function of incident solar wavelength. The results presented here show an impact of VUV irradiation from 115 to 165nm on PTFE diffusers as manifested by non-negligible changes in their measured directional reflectance from 250nm to 400nm. Previous studies performed in our lab revealed that irradiation above 180nm over typical mission exposure times produced changes in the directional reflectance of uncontaminated PTFE less than our 1% (k=1) BRDF measurement uncertainty.

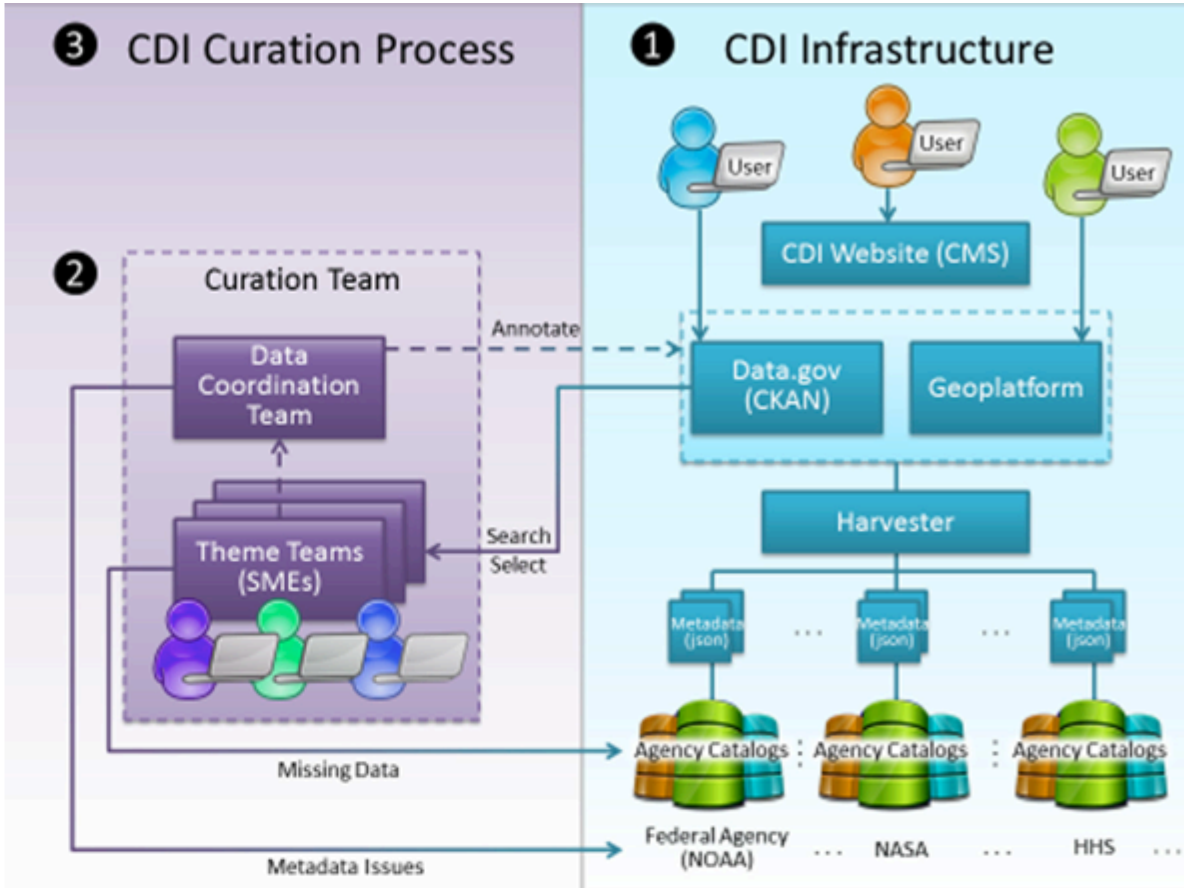
Results from this study is of interest to government, university, and industry remote sensing scientists and engineers. Information from this work aids in the optimal design of on-orbit solar diffuser calibration systems, provides guidance into minimizing pre-launch and on-orbit contamination, and provides quantitative insight into the development and refinement of instrument radiometric math models from which calibration and instrument measurement uncertainties are derived.

(1) Stiegman, A.E., Bruegge, C.J., and Springsteen, A.W. 1993 Ultraviolet stability and contamination analysis of Spectralon diffuse reflectance material Opt. Eng. **32** 799-804.

Curating Climate Resilience Data for the Climate Data Initiative

Curt Tilmes, Ana Pinheiro Privette, Terrestrial Information Systems Laboratory, NASA GSFC

Rahul Ramachandran, Kaylin Bugbee, NASA MSFC



NASA Supported the Geocuration of Climate Resilience data submitted to the Climate Data Initiative.

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References:

Rahul Ramachandran, Kaylin Bugbee, Curt Tilmes and Ana Pinheiro Privette, Climate data initiative: A geocuration effort to support climate resilience, *Computers & Geosciences*, Volume 88, March 2016, Pages 22-29, ISSN 0098-3004, http://dx.doi.org/10.1016/j.cageo.2015.12.002.

Data Sources:

Curation and presentation of climate related data through http://climate.data.gov.

Technical Description of Figures:

Graphic 1:
This figure provides an overview of the Climate Data Initiative Curation process and participants based on roles and infrastructure components used to publish the final results through the CDI web site http://climate.data.gov.

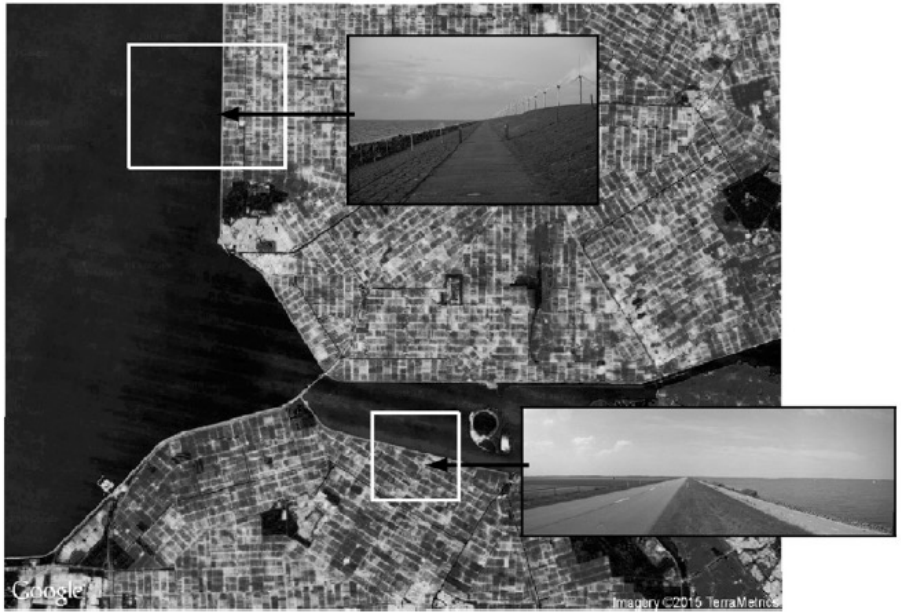
Scientific significance, societal relevance, and relationships to future missions:

This paper introduces the concept of geocuration, defined as the act of searching, selecting, and synthesizing Earth science data and metadata and information from across disciplines and repositories into a single, cohesive and useful collection. It presents the Climate Data Initiative (CDI) project as a prototypical example of geocuration. The CDI is a broad multi-agency effort of the U.S. government and seeks to leverage the extensive existing federal climate-relevant data to stimulate innovation and private-sector entrepreneurship to support national climate-change preparedness. NASA is responsible for a systematic effort to manually curate and share openly available climate data from various federal agencies.

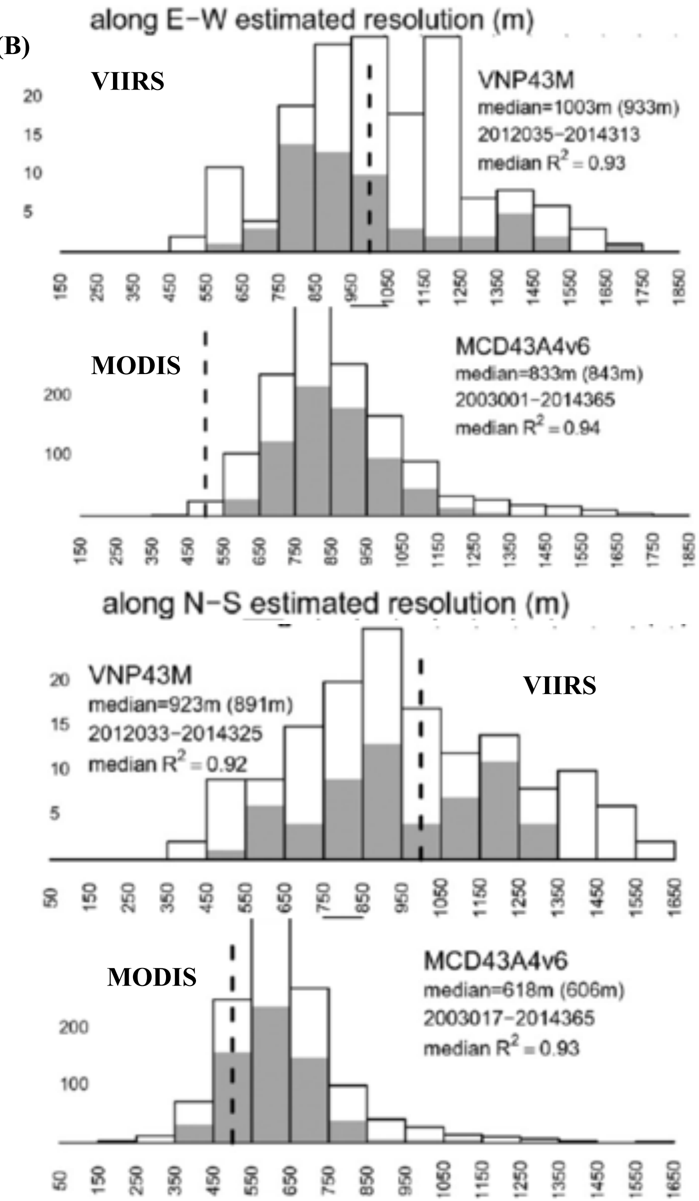
Estimating the effective spatial resolution of the operational BRDF, albedo, and nadir reflectance products from MODIS and VIIRS

Zhousen Wang and Miguel O. Román, Terrestrial Information Systems, NASA GSFC

(A)



(B)



The effective spatial resolution of 500 m gridded MODIS BRDF/Albedo/NBAR products is about 700m. The VIIRS 1km gridded product is close to its effective spatial resolution.

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References:

Campagnolo, M.L., Sun, Q., Liu, Y., Schaaf, C.B., Wang, Z., Román, M.O. (2016). Estimating the effective spatial resolution of the operational BRDF, albedo, and nadir reflectance products from MODIS and VIIRS, *Remote Sensing of Environment*, 175, 52-64, http://dx.doi.org/10.1016/j.rse.2015.12.033

Wang, Z., Schaaf, C.B., Strahler, A.H., Chopping, M.J., Román, M.O., Shuai, Y., ... Fitzjarrald, D.R. (2014). Evaluation of MODIS albedo product (MCD43A) over grassland, agriculture and forest surface types during dormant and snow-covered periods. *Remote Sensing of Environment*, 140, 60–77. http://dx.doi.org/10.1016/j.rse.2013.08.025.

Román, M.O., Schaaf, C.B., Woodcock, C.E., Strahler, A.H., Yang, X., Braswell, R.H., ... Goulden, M.L. (2009). The MODIS (Collection V005) BRDF/albedo product: Assessment of spatial representativeness over forested landscapes. *Remote Sensing of Environment,* 113(11), 2476–2498. http://dx.doi.org/10.1016/j.rse.2009.07.009.

Data Sources: MODIS BRDF/Albedo (MCD43A) products were downloaded from NASA Level 1 and Atmosphere Archive and Distribution System (LAADS) website. VIIRS BRDF/Albedo (VNP43M) products were produced offline using the same package for NASA VIIRS standard product.

Technical Description of Figures:

Graph (A): Google maps image retrieved April 10, 2015 of the study area in the Netherlands (Lat=52.697°N, Long=5.593°E). This location was chosen for the large size linear natural targets. The white boxes indicate the approximate positions of the sub-images around the NS edge (top) and the EW edge (bottom) where reflectance products were extracted. The inserted pictures show the sharp transitions between water and a surface mostly covered by vegetation.

Graph (B): Distribution of estimated resolutions for MODIS and VIIRS BRDF/Albedo product along east-west and north-south directions. The gray portion of the histogram corresponds to high inversion quality (more than 50% of full inversions). The median estimated resolution (between parentheses, the median estimated resolution for high inversion quality), the range of dates and the median goodness of fit for all observations are indicated near each histogram. The dotted lines indicate the nominal grid size of the product. Theoretical experiences have suggested that MODIS product would be representative of a larger surface area than the 500 m. The 1 km gridded VIIRS BRDF/Albedo product is generated from 750 m VIIRS data. This research both quantifies that effect, and verifies that the spatial effective resolution is consistently less than 1 km for MODIS and VIIRS.

Scientific significance, societal relevance, and relationships to future missions: Satellite derived surface albedo and view-angle corrected surface reflectance products serve as the key inputs for an array of climate, biogeochemical, and hydrologic modeling efforts. This research effort is particularly focused on establishing the effective spatial resolution of the global MODIS and VIIRS Nadir BRDF-Adjusted Reflectance (NBAR) and Albedo products. The MODIS BRDF/Albedo/NBAR products (and into the future with the analogous VIIRS products) are increasingly being relied upon to monitor vegetation phenology, identify land cover and land cover disturbance, track snowfall and melt, and establish surface energy balance variability. Thus, this research provides the quantification both for MODIS and VIIRS necessary for the effective use of these products by the global modeling and monitoring communities.